Systems Research Forum
Vol. 5, No. 2 (2011) 109–141

DOI: 10.1142/S1793966611000308

ESTABLISHING AN OPERATIONAL CONTEXT FOR EARLY SYSTEM-OF-SYSTEMS ENGINEERING ACTIVITIES

BRYAN HERDLICK

Johns Hopkins University/Applied Physics Laboratory
Patuxent River Field Office 46579 Expedition Drive
Suite 300, Lexington Park, MD, 20653, USA
bryan.herdlick@jhuapl.edu

Investigation of the engineering trade-space associated with complex capabilities and system-of-systems (SoS) solutions is often pursued outside the purview of an over-arching Major Defense Acquisition Program. As a result, many of the mandates associated with the United States Department of Defense (DoD) acquisition process may not be levied upon such activities. However, since establishing an operational context for system or capability development remains a systems engineering best practice, the requirement for a concept of operations document should be given favorable consideration. Unfortunately, the myriad variants of CONOPS in the DoD (and the organizational pedigree associated with each) can generate misunderstanding and disagreement over authorship, ownership, approval authority, and the intended purpose of the document. The title alone can undermine the utility of an operational context document and result in its misinterpretation or rejection. This paper compares guidance on the development of operational concept documents from industry, DoD and U.S. military services and compares them with related documents that are sometimes confused with (or inappropriately substituted for) CONOPS. A new method for establishing an operational context for SoS-based capability development is presented as an alternate to the aforementioned documents.

Keywords: CONOPS, concept of operations; CONEMPS, concept of employment; OCD, operational concept description; DRM; DRMP, design reference mission profile; SoS, system of systems; concept development; technology development; engineering development; CBA, capability-based analysis.

1. Introduction

Chairman of the Joint Chiefs of Staff Instruction (CJCSI, 2007) 3710.01 defines a capability as "The ability to achieve a desired effect under specified standards and conditions through a combination of means to perform a set of tasks to execute a specified course of action." However, the language in the 3710.01 series of instructions speaks more to documenting the requirements associated with a single program rather than articulating the concept of a *composite* capability that must be achieved through *multiple* programs. Such a distributed design is, by definition, a system of systems (SoS) and achieves a capability greater than that delivered by the constituent systems acting independently. While it may be successfully argued that a fighter aircraft or a surface combatant may satisfy the technical definition of a SoS, such examples are normally developed through a singular major defense acquisition program (MDAP) and do not evidence the additional organizational complexity associated with a SoS constructed from multiple MDAPs. The challenges associated with the management and development of such SoS-based capabilities have received much attention in recent years. An article in the journal *Systems Engineering*, titled “System of Systems Lead System Integrators: Where Do They Spend Their Time and What Makes Them More or Less Efficient” (Lane and Boehm, 2008) offers an excellent overview of those challenges and an introduction to 20 other references in the topic area. Within the US Department of Defense (DoD), the Office of the Undersecretary of Defense for Acquisition and Technology issued a Systems Engineering Guide for Systems of Systems (ODUSD (A&T)SSE, 2008) to introduce terminology and consolidate applicable best practices. Finally, in the summer of 2009, the International Council on Systems Engineering (INCOSE) proposed a Research Plan (Ferris, 2009) that identified SoS as one of seven key areas of interest, with specific emphasis on a need for SoS-specific methodology and documentation. This paper offers a contribution to the methodology and documentation associated with the development of SoS-based capabilities — specifically the establishment of an operational context for early systems engineering activities.

In the lexicon of the SoS SE guide, this paper focuses attention on “Acknowledged” SoS. The SoS SE guide cedes that often only some of the characteristics offered in the definition of an “Acknowledged” SoS are met. Specifically, the assignment of a “designated manager” and the allocation of “resources for the SoS” may manifest as an ad hoc “coalition of the willing,” possibly facilitated by a lead integrator and executed through “creative” funding vehicles. Additionally, while it may be true that “...constituent systems retain their independent ownership, objectives, funding, and development and sustainment approaches...” it must be stressed that this applies only to previously established, system-specific functionality *not* associated with the SoS-based capability under development. Finally, the statement that “Changes in the systems are based on collaboration between the SoS and the system” incorrectly implies that a SoS development effort is backed by an organizational entity that is similar to the program offices responsible for management of the constituent systems that comprise the SoS.

In spite of the extensive treatment given SoS challenges in systems engineering professional journals and conferences, and even following the publication of the DoD SoS SE Guidebook, the pursuit of complex capabilities through SoS solutions continues to vex those charged with the management of such efforts. The development of a SoS-based capability is often a messy, iterative process that alternates between problem definition and exploration of the solution space — unavoidable, perhaps, when addressing “Wicked Problems” (Conklin, 2005) but an application for which the linear DoD acquisition processes are ill-suited. As a result, the exploration of SoS solutions is normally pursued *outside* the purview of a single over-arching, capability-focused MDAP.[a] Some excerpts from the DoD Instruction for "Operation of the Defense Acquisition System" (DoDI 5000.2, 2008) are introduced in the following paragraphs to frame the ad hoc approach to SoS development prevalent today in the U.S. DoD. Italics have been introduced by the author for emphasis.

It is not uncommon for concept development and technology development activities to be pursued outside the purview of (often as a precursor to) a MDAP. Often, a team comprised primarily of scientists and engineers must craft an operational context to inform concept development, technology development and early engineering development activities. Examples of such efforts are detailed in the excerpt from DoDI 5000.2, below. Crafting an operational context for an advanced capability — especially one that challenges present-day warfighting doctrine and tactics — requires more than a compilation of existing Concepts of Operations, weapon systems operating manuals, DoD capability/requirements documents, and system specifications. This paper offers a method for addressing this challenge.

> TECHNOLOGY PROJECTS. Joint Experimentation, *Defense Advanced Research Projects Agency* projects, the Technology Transition Incentive Program, SBIR and Small Business Technology Transfer Programs, the Joint Integration and Interoperability Program, Joint Capability Technology Demonstrations, the Coalition Warfare Program, the Quick Reaction Special Projects/Rapid Reaction Fund, Foreign Comparative Testing, the Defense Acquisition Challenge Program, the Joint Test and Evaluation Program, the Joint Improvised Explosive Devices Defeat Office, the Rapid Reaction Technologies Office, and Defense Biometrics *are some of the activities that facilitate and provide early joint technology and capability definition, development, experimentation, refinement, testing, and transition. The USD (AT&L) shall be the MDA [Milestone Decision Authority] for those projects that, if successful, will likely result in an MDAP* or MAIS program unless the USD (AT&L) delegates milestone decision authority for a MAIS program.[b]

Early concept and technology development activities for a SoS-based capability often deviate from those associated with a single-system solution that might constitute a candidate MDAP upon completion. In the excerpt immediately below, DoDI 5000.2 highlights steps that still must occur (author's italics) in the development of a SoS solution, but also clearly reflects the constraints of the traditional acquisition process. Due to the nonlinear nature of complex capability development, the DoD acquisition process for MDAPs often cannot be neatly applied to SoS solutions and a clear break-point (e.g., Milestone B) between technology

[a] The U.S. Army Future Combat System (FCS) is often presented as an exception to this statement. While it makes for an interesting and educational case study in its own right, it has not become a template for successful development, management, or acquisition of SoS-based solutions within DoD.
[b] Department of Defense Instruction 5000.2, USD(AT&L), 2 December 2008 (Enclosure 3, p. 30).

development (TD) and engineering and manufacturing development (EMD) cannot be identified. Furthermore, the latitude to permit a system to enter the acquisition process at Milestone C, given satisfaction of EMD exit criteria (second excerpt, below), substantiates the claim that DoD regularly conducts activities from Concept Development through Engineering and Manufacturing Development *outside* the purview of an MDAP.

> *The project shall exit the Technology Development Phase when an* affordable program or *increment of militarily useful capability has been identified*; the technology and manufacturing processes for that program or increment have been assessed and demonstrated in a relevant environment; manufacturing risks have been identified; a system or increment can be developed for production within a short timeframe (normally less than five years for weapon systems); or, when the MDA decides to terminate the effort. *During Technology Development, the user shall* prepare the capability development document (CDD) to support initiation of the acquisition program or evolutionary increment, *refine the integrated architecture, and clarify how the program will lead to joint warfighting capability.* The CDD builds on the ICD and provides the detailed operational performance parameters necessary to complete design of the proposed system. A Milestone B decision follows the completion of Technology Development.
>
> ENGINEERING AND MANUFACTURING DEVELOPMENT (EMD) PHASE. The purpose of the EMD Phase is to *develop a system or an increment of capability; complete full system integration* (*technology risk reduction occurs during Technology Development*); develop an affordable and executable manufacturing process; ensure operational supportability with particular attention to minimizing the logistics footprint; *implement human systems integration* (*HSI*); design for producibility; ensure affordability; protect CPI [critical protected information] by implementing appropriate techniques such as anti-tamper; and *demonstrate system integration, interoperability*, safety, *and utility.* The CDD, Acquisition Strategy, SEP [systems engineering plan], and test and evaluation master plan (TEMP) shall guide this effort. EMD begins at Milestone B, which is normally the initiation of an acquisition program. There shall be only one Milestone B per program or evolutionary increment. *Each increment of an evolutionary acquisition shall have its own Milestone B unless the MDA determines that the increment will be initiated at Milestone C.* At Milestone B, the MDA shall approve the Acquisition Strategy and the acquisition program baseline (APB). The MDA decision shall be documented in an ADM [acquisition decision memorandum]. The tables in Enclosure 4 identify the statutory and regulatory requirements that shall be met at Milestone B.

The exploration of SoS engineering trade space, given its nonlinear nature and the asynchronous program timelines of the constituent systems, makes necessary the simultaneous conduct of concept development (CD), TD and EMD activities. Collaboration between existing program offices, platform/system contractors, and organizations from the S&T, R&D, and acquisition engineering disciplines is thus required, and a *virtual* organization forms that must operate in parallel with the traditional acquisition process as it applies to MDAPs. Without the auspice of an over-arching MDAP for the SoS, however, much of the burden *and benefit* of the formal DoD acquisition process can be missing — such as the requirement for a well-developed operational context to guide development activities (e.g., a CONOPS document is mandated *for MDAPs* by the Clinger−Cohen Act via DoDI 5000.2). However, the fact that DoD acquisition processes and organizations are not well suited to SoS development should not be construed as license for departure from sound systems engineering best practices. Identification of an operational context for the development of a new SoS-based capability is arguably even *more* important, as substantiated in the aforementioned DoD SoS SE Guide:

> Logical Analysis is the first major step in Developing and Evolving and SoS Architecture. An important starting point is the CONOPS for the SoS. How will the SoS be employed in an operational setting? What are trigger conditions? What is the range of scenarios? Who are the key participants and what are the constraints on their actions? In developing the architecture for the SoS, the SoS systems engineer develops a structured overlay atop the set of constituent systems supporting SoS objectives, addressing key questions about the SoS, including: Which systems provide what functionality to the SoS? What are the end-to-end threads for the SoS? What behavior is expected of the systems? What data need to be exchanged to implement the threads?

A key contributor to the DoD SoS SE guide, Judith Dahmann, recently co-authored an article that appeared in the January 2011 issue of IEEE Aerospace and Electronic Systems that further describes a "SoS CONOPS" as follows:

> The SoS CONOPS describes how the functionality of the systems in the SoS will be employed in an operational setting. The CONOPS is developed by operational users and with active participation from the SoS systems engineers to describe the way users plan to operate and use systems to achieve the objectives, as influenced by the various environments and conditions anticipated. It is developed in parallel with the capability objectives. As the capability objectives evolve, the CONOPS should evolve in detail, as well. SoS management and SE teams use the CONOPS to define the SoS requirements space, to identify aspects of systems which could impact SoS design, and to select performance metrics and test environments, [further characterized by/as:] Multiple system focus. Often developed after constituent systems have been fielded; Evolves over time, sometimes substantially.

While attempting to reinforce sound systems engineering practices during SoS development, both of these excerpts use the term "CONOPS" as an appropriate acronym, but perhaps without consideration for the fact that the term can imply different content and purpose to the participants and stakeholders in the SoS development effort. Furthermore, since early SoS development efforts are often led and conducted by engineers and scientists — *to include the initial definition of the operational context for the complex capabilities they deliver* — any associated "CONOPS" constitutes a source of friction and inefficiency due to disagreement over content, authorship, ownership, approval authority, and the intended use of the document.

From a perspective admittedly more focused on the U.S. Navy, this paper compares industry, DoD and service-specific guidance for CONOPS with that for related documents that are sometimes confused with (or inappropriately substituted for) CONOPS. Information elements critical to the development of SoS-based capabilities are identified and assembled to create a new document that is uniquely suited to early systems engineering activities associated with SoS development.

2. Industry "CONOPS"

Guidance on the development of an operational concept or concept of operations (CONOPS) (the terms are often used inter-changeably outside DoD) can be found in many industry references (IEEE, 2007), (INCOSE, 2007) and generally details how a system will be used from the operator/user perspective. For instance, The Handbook of Systems Engineering and Management (Sage and Rouse, 1999) characterizes an "operational concept document (OCD)" as a product that should:

> "[capture]... how the system will be used during the operational phase, [and] the reasons the system has for existing." Development of such a product "... depends on a thorough understanding of the *missions that the system must perform and the environment that the system will have to operate in.* Hence the systems engineer works closely with the users or their representatives to write the operational requirements. Together, they describe the *major functions and operational characteristics desired for a system. How the system operates*, *where in the operating environment the system will be distributed*, *how long the system must operate*, *and how effective the system' s performance must be are all part of the operational concept. Care is taken not to specify technical solutions* but to describe the performance desired of the new or improved system. Usually the operational concept describes the typical mission profiles or operational scenarios of the system."

3. CONOPS in the U.S. Navy

While CONOPS developed within the U.S. DoD may fit the industry-representative definition presented above in most respects, they can often be quite specific as to the technical solution and supportability aspects — a deviation from the above definition. Additionally, DoD CONOPS can also evidence "organizational pedigrees" that can imbue them with an identity that is every bit as important as the content of the document. OPNAV Instruction 5401.9 (DoN, 2010), which details the Navy Concept Generation and Concept Development Program, identifies two broad categories of CONOPS within the Navy — "acquisition" and "Fleet." Specifically, it states that "[CONOPS can be]. . .a document generated by the Office of the chief of Naval Operations (OPNAV) [used in the] Department of the Navy requirements and acquisition governance process or a fleet CONOPS."

In a 2006 briefing, the Navy's Fleet Forces Command depicts CONOPS development responsibilities within the Navy, as promulgated by a Navy Corporate Board decision of February 2005. The graphic identifies the OPNAV as being responsible for CONOPS that address future requirements (*beyond* the Future Years Defense Plan; FYDP) with such CONOPS approved by the Chief of Naval Operations (CNO). The Commander of Fleet Forces Command (CFFC) is identified as the Fleet's consolidated and authoritative voice charged with approval of CONOPS *within* the FYDP. The Naval Warfare Development Command (NWDC) is responsible for managing the CONOPS enterprise on behalf of the Navy.

In Fig. 1, acquisition CONOPS are developed by the organizations in the upper dark-blue ovals, and fleet CONOPS are developed by warfighting organizations in the lower dark-blue ovals. This figure indicates that ***ALL*** Navy CONOPS (except those associated with real world and training operations — which imply yet more CONOPS categories) are tracked by NWDC and validated by CFFC — a questionable representation given the myriad variants of CONOPS employed within the Navy's acquisition activities. The validity of this approach to CONOPS development

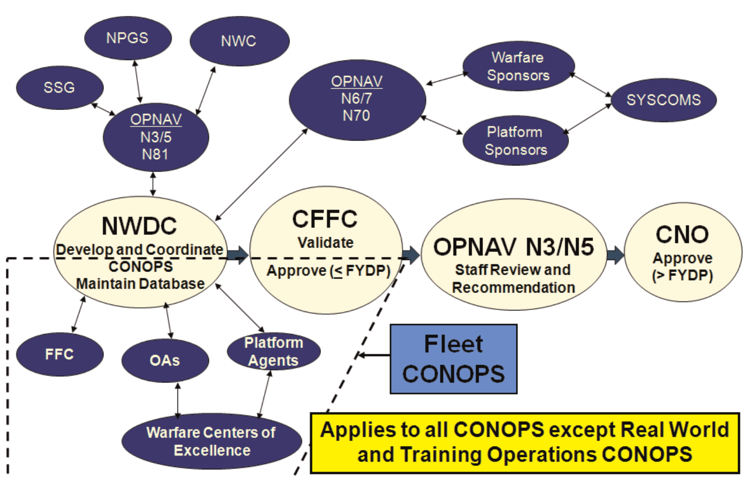

Fig. 1. (Color online) CONOPS Management Process as defined by the OPNAV Corporate Board, 2005 (from the Fleet Forces Command CONOPS Guidance Brief of October 2006).

and management is further challenged in application to SoS solution, where existing platforms and systems are modified and integrated (*within* the FYDP), and augmented by new systems (*within and beyond* the FYDP), to deliver increments of warfighting utility (*within* the FYDP) in pursuit of a composite capability that may not be realized until *beyond* the FYDP.

Acquisition and Fleet CONOPS are introduced briefly in the following paragraphs to support subsequent evaluation of their merits and shortfalls in application to early SoS engineering activities.

3.1. *Operational (Fleet) CONOPS*

Operational CONOPS are described in Joint Publications, instructions from the Joint Chiefs of Staff, and guiding documents from the individual military services. From the perspective of the Chairman of the Joint Chiefs of Staff, as reflected in Instruction (CJCSI, 2006) number 3010.02b, CONOPS in the context of Joint Operating Concepts (JOpsC) and capability-based analysis (CBA) are focused on military operations and the employment of forces *beyond the FYDP*. This instruction states that "The Secretary of Defense approves a set of threat-based classified defense planning scenarios (DPSs). They are informed by the effects and military capabilities outlined in the JOCs and JFCs to develop classified blue force CONOPS. The scenarios, in turn, are used during the CBA of JICs [*Joint Integrating Concepts*]." It further details the role of CONOPS pursuant to the family of JOpsC documents as follows:

> For JOpsC family development, CONOPS are *used to provide the overall understanding of an operation and the broad flow of tasks assigned to subordinate and/or supporting entities. It presents a joint force commander's plan that synchronizes military capabilities to accomplish the mission for a specific scenario* 8–20 *years into the future.* CONOPS focus on describing the streams of activities and how the joint force commander might organize and employ forces to accomplish those activities. CONOPS used in the JOpsC family development process are based on DPS or illustrative vignettes:
>
> (a) Defense Planning Scenarios. DPSs, written 8–20 years into the future, are used in CBA. These scenarios have classified CONOPS that provide a high level of specificity and defined parameters *to aid in robust analysis of capabilities and a comparison of alternate solutions.*
> (b) Illustrative Vignettes. When used in JOpsC, illustrative vignettes provide operational context to describe *how a joint force commander might organize and employ forces* 8–20 years into the future. These vignettes are used to clarify and increase understanding of the concepts.

At the military service level, the U.S. Navy's Fleet CONOPS Writer's Guide states that the Fleet CONOPS Development Team "...collaborates with the CNO resource sponsors for supporting information from related studies/analyzes and ensures consistency with what capabilities are expected within the FYDP." It also depicts Fleet CONOPS as sharing "top-down guidance" with the Concept Development process, and benefitting from "lessons learned" from exercises, operational planning documents and "real-world operations" (see Fig. 2). In execution, however, the focus on near term capabilities (i.e., systems currently fielded, or soon to field; *within the FYDP*) and operational applications is reflected in the format and content of the two variants of Fleet CONOPS — "Warfighting" and "Platform Wholeness." Subsequent review will reveal that these documents are ill-suited to DoD acquisition and technology development activities.

By comparison, the U.S. Air Force defines CONOPS in their Concept of Operations Development Instruction (AFI 10-2801, 2005) as a document that "...delineates the *highest Service-level concept comprising a commander's assumptions and intent* to achieve desired effects through the guided integration of capabilities and tasks that solve a problem in an expected mission area." This instruction further states that "...Joint Force Commanders employ [AF CONOPS] through Air Expeditionary Forces to fight and win wars." This instruction goes on to identify "the seven" AF CONOPS as: "Global Strike, Global Persistent Attack, Homeland Security, Nuclear Response, Global Mobility, Space and Command, Control, Communications, Computer, Intelligence, Surveillance and Reconnaissance, and Agile Combat Support. This definition reflects a decidedly operational perspective, and aligns well with CONOPS as described in the U.S. Navy's Fleet CONOPS Writer's Guide (DoN, 2009), but is not intended to directly serve DoD acquisition or technology development activities.

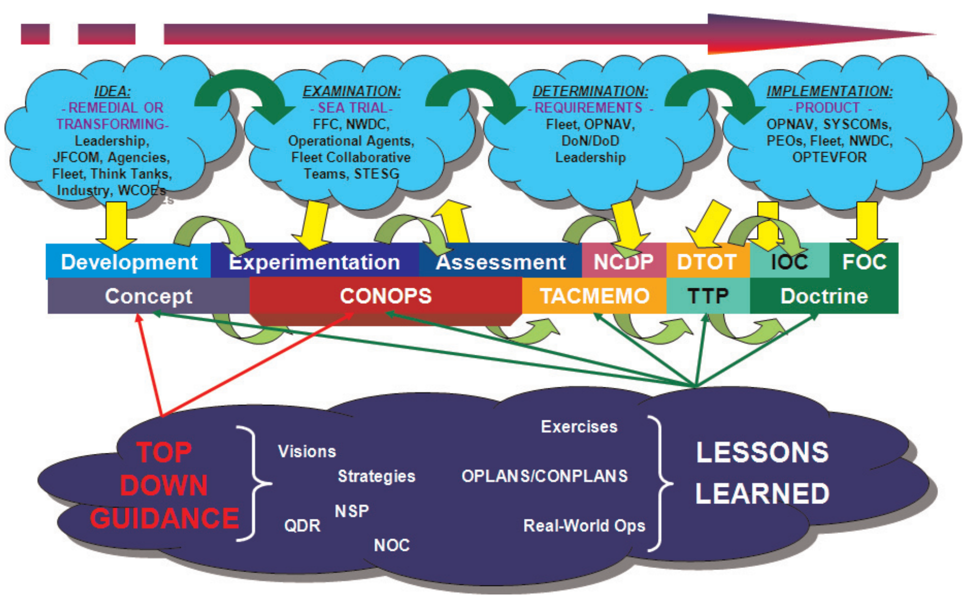

Fig. 2. "Concept to CONOPS to Doctrine" Transition (a variant of Fig. 1-1 from the CFFC Fleet CONOPS Writer's Guide).

3.1.1. *Warfighting CONOPS*

In Chief of Naval Operations Instruction (OPNAVINST) 5401.9, the U.S. Navy states that "A Fleet warfighting CONOPS [specifies] how the fleet will employ current capabilities and/or capabilities that will reach initial operational capability (IOC) within the Future Years Defense Plan." The Fleet CONOPS Writing Guide states that "The primary purpose of a CONOPS is to bridge a concept to delivery of a capability to the warfighter." It further defines a Fleet Warfighting CONOPS as: "A formal document specifying how the Fleet employs current capabilities or will employ capabilities that will reach IOC *within the FYDP*..." and specifies that "The primary audience for Warfighting CONOPS is those who plan and execute the U.S. Navy missions." The U.S. Navy's Fleet CONOPS Writing Guide provides a general format for Warfighting CONOPS as Appendix C. Topic headings include a letter of promulgation, an executive summary (with a DOTMLPF[c] focus), purpose/statement of intended use for the document, scope of the document, scenarios and how capabilities may be employed [unique to Warfighting CONOPS], details on manning and training (if applicable), DOTMLPF considerations, and validation requirements.

3.1.2. *Platform wholeness CONOPS*

OPNAVINST 5401.9 distinguishes a Fleet Platform Wholeness CONOPS from a Warfighting CONOPS in that it specifies "...how the Fleet *mans*, *trains*, *equips and maintains new capabilities* that will reach IOC *within the FYDP*. It informs programs of record (PORs) of the Fleet's needs and intent. The primary audience for the Fleet Platform Wholeness CONOPS is the platform's type commander (TYCOM) and supporting organizations." The Fleet CONOPS Writing Guide provides a general format for Platform Wholeness CONOPS as Appendix C. Topic headings for a Platform Wholeness CONOPS differ slightly from a Warfighting CONOPS and include a letter of promulgation, an executive summary (with a DOTMLPF focus), purpose/statement of intended use for the document, scope of the document, a description of the platform in terms of capabilities and concept (unique to Platform Wholeness CONOPS), an analysis of the operations of the platform (unique), a description of administrative control and operational chain of command (unique), details on manning and training (if applicable), support requirements, DOTMLPF considerations, and validation requirements. Notably, scenario(s) and how a platform may be employed are *not* topics normally addressed by a Platform Wholeness CONOPS.

3.2. *Acquisition CONOPS*

Many variants of CONOPS are developed within the DoD acquisition construct, and may serve to inform the development of maintenance plans, security processes,

[c] DOTMLPF is an acronym for Doctrine, Organization, Training, Materiel, Leadership, Personnel and Facilities — it serves as a tool for quickly referring to those aspects of fielding, support and employment that exceed the immediate scope of weapon system design and production.

training programs, or system and capability development. Chairman of the Joint Chiefs of Staff Instruction 3710.01 defines the Joint Capability Integration and Development System (JCIDS) and associated "requirements" documentation, and limits the scope of an acquisition CONOPS to a timeframe *within the FYDP.* It states that a (acquisition) CONOPS is intended to detail "*. . .how a joint force commander may organize and employ forces in the near term* (*now through seven years into the future*) *in order to solve a current or emerging military problem. These CONOPS provide the operational context needed to examine and validate current capabilities and may be used to examine new and/or proposed capabilities required to solve a current or emerging problem.*" This wording implies the CBA process used to identify warfighting capability gaps and prospective solutions, to include an Analysis of Alternatives (AoA). In DoD Instruction 5000.02, such CONOPS are referred to as "preliminary CONOPS" (see excerpt, below) and are introduced as an integral part of the initial requirements development process. Such CONOPS are closely affiliated with an initial capability document (ICD) and precede an AoA. While such a "preliminary CONOPS" may offer an early articulation of an operational context, it is not intended to provide adequate detail to support technical or engineering development activities.

> At the Materiel Development Decision review, the Joint Staff shall present the JROC recommendations and the DoD Component shall present the ICD including: the *preliminary* CONOPS, a description of the needed capability, the operational risk, and the basis for determining that nonmateriel approaches will not sufficiently mitigate the capability gap. The Director, Program Analysis and Evaluation (DPA&E), (or DoD Component equivalent) shall propose study guidance for the AoA.

The National Research Council's U.S. Air Force Study Board (NRC, 2008) further describes a "preliminary" CONOPS as a product that follows concept creation/identification, and precedes performance assessments and architecture development. They state that early in the capability development process (i.e., pre-Milestone A), a *preliminary* CONOPS should be developed that ". . .is a top-level description of how a system and its operators and users will interact to produce the required capability, including operation in a SoS. At Milestone A, the CONOPS needs to be sufficient to ensure that the chosen concept is capable of operating to produce the desired outcomes and time lines. A key precursor of a CONOPS is often a description of the other systems with which the system of interest will be interacting and an understanding of what the user expects the system to do in its operating environment." Given that the "preliminary" CONOPS mentioned in DoDI 5000.2 is introduced as an integral part of the ICD and further discussed in a U.S. Air Force context as a pre-Milestone A product, it presents as a *precursor* to the CONOPS mandated for MDAP s by the Clinger−Cohen act.[d]

[d] Enclosures 4 and 5 of DoDI 5000.2, taken together, are required to construct the requirement for the "acquisition" CONOPS required for DoD acquisition Milestones.

The Navy's Fleet CONOPS Writer's Guide depicts "acquisition" CONOPS as any variant of a "concept of operations" that is developed by OPNAV and *not* approved by Fleet Forces Command. A more specific definition for an acquisition CONOPS may be found in OPNAV Instruction 5401.9 which states that such a document shall offer "...a description of capability employment, sustainment, basing, training and manning *to support life-cycle cost estimates*." This is quite different from the purpose identified for Operational (Fleet) CONOPS. Historically, there has been no clear guidance for how best to identify an operational context for technical and early engineering development activities. Recently, however, a draft OPNAV Instruction for a Developmental System Concept of Operations was produced and is under review for approval as of May 2011. OPNAV Instruction 5401.xx (2010) (no final identifier assigned) detail a variant of acquisition CONOPS and identifies it as an accompanying document to the capabilities development document (CDD) required at Milestone B for MDAPs. Based on its availability at MS B, it must be presumed suitable as a guide for engineering and manufacturing development efforts, and satisfactory from the standpoint of the Clinger−Cohen Act. However, it is not intended as a guide for early concept development and technology development. Furthermore, the instruction (in its draft form) clearly states that it applies to MDAPs, pre-MDAP programs, and Rapid Deployment Capability programs — not *ad hoc* SoS development efforts executed asynchronously through those MDAPS.

4. CONOPS Surrogates and Imposters

In an effort to avoid perceived conflict over content, authorship, ownership, and approval authority, it is not uncommon for other "recognized" documents to be selected as an alternative to a CONOPS — if only to affix a different name to a document with similar content and purpose. The most common CONOPS "surrogates" include "Concepts of Employment (CONEMPS)" and "Design Reference Mission Profiles (DRMP)." Other documents that present as contenders for the role of CONOPS include "Concept Development Proposals" and "Operational Concept Descriptions". Each of these prospective alternatives to a CONOPS is introduced briefly in the following paragraphs to support a subsequent evaluation of their merits and shortfalls in application to early SoS engineering activities.

4.1. *Concepts of employment*

CON*EMPS* is a term that has been used to identify CONOPS documents developed in support of early system development activities in the DoD acquisition process. As previously mentioned, draft OPNAV Instruction 5401.xx (under review) seeks to replace the term CON*EMP* with term *Developmental System* CONOPS as a means to distinguish this variant of CONOPS from those used in the fleet. Confusing the issue, however, are (as an example) CONEMP documents developed by NATO for the integration of unmanned air systems, and use of the term by the United Kingdom Ministry of Defense which identifies CON*OPS* and CON*EMPS* as separate documents developed in a sequence of increasing maturity (U.K. MoD, 2005) — a relationship opposite to that historically followed within U.S. Navy acquisition channels, as detailed in OPNAVINST 5401.xx.

4.2. *Design reference mission profile*

In a technical briefing of 2002, the Assistant Secretary of the Navy for Research, Development and Acquisition defined a Design Reference Mission Profile (DRMP) as "... a time history or profile of events, functions (often referred to as use or operations) and environmental conditions that a system is expected to encounter during its lifecycle, from manufacturing to removal from service use" (ASN(RD&A), 2002). They further detail the content and scope of a DRMP as follows:

> Proper definition of the DRMP includes not only the expected nominal climatic conditions, but also worst-case, rate of change, synergistic conditions, and conditions of assembly, packaging, handling, shipping, storage, maintenance and transportation. The significance of induced environments (i.e., environmental conditions that are predominantly man-made or generated by the materiel platform) is often overlooked. Therefore, it is essential that conditions such as repetitive shock or transient vibration caused by gunfire, fluctuating pressure loadings caused by acoustic noise, aerodynamic turbulence, pyrotechnic shock, near miss shock and electromagnetic environments be considered during the development of the DRMP." "It is important [that the DRMP identifies] appropriate values for material design and test related criteria [to include] realistic environmental parameters and material-specific parameter levels associated with environment-related issues and criteria.

In 2000, Skolnik and Wilkins detailed the role of a DRM[e] within the DoD acquisition process and depicted it as a predecessor to the development of concepts and requirements. Specifically, they stated that:

> *The DRM concept seeks to define the problem, not the solution. Its primary objective is to characterize the threat and operating environment* that will serve as the baseline to support systems engineering activities, i.e., requirements definition/refinement, concept development/evaluation, trade study analysis, design, test and evaluation, etc.

[e] Additional references for DRM and DRMP are desired, as the difference between the two is not clear based on guiding documents available during the creation of this point-paper. Based on the author's experience, the two terms are often used interchangeably, although the term DRM is often used to refer to a more prosaic document with a broader scope (i.e., not limited to just chronological tables of functions and environmental conditions).

An extract from a "real-world" DRMP purpose statement is presented below to further demonstrate the unique nature of the DRMP. The italicized, underlined text is indicative of the relationship between the DRMP and both the systems engineering process, and the scenarios normally associated with a CONOPS document. Of note, the DRM is presented as a reference for engineering activities and the subsequent development of scenarios — it does not, however, contain operational scenarios.

> Because the [system name removed] is considered an on-demand system, an understanding of when it is required to be operational is needed. Therefore the DRMP has been designed to explain the high level, time-sequenced profile of a single [platform/system] sortie. *The DRMP provides a baseline which can be used to assess and establish consistency between the CDD performance requirements and the tactical application of the system.* The document also serves as a basis for campaign and mission analyzes. *The profile provides a reference mission which can be used as a systems engineering input.* Consistent with the CDD's definition of the system, the DRMP also *delineates the [platform/system] boundaries and the interface [with] outside systems.* By establishing these system boundaries, the DRMP defines the system components which are included in calculating system reliability, maintainability, and availability. The DRMP also provides a baseline definition for mission start time and completion time and identifies the timeframe within a mission which is used to calculate an area search rate. Finally, *the DRMP provides a mission profile baseline for use in designing scenarios for developmental and operational testing* of the [platform/system] as well as supporting what will be considered operational uptime, downtime, and neutral time.

The ASN(RD&A) DRMP guide states that "A common method used is a series of charts/matrices that, as a composite, identify and describe, in sequence, the pertinent functions and environments and their parameter ranges." Content is further detailed as addressing a functional and environmental profile. The functional profile is characterized by things such as packaging, handling, shipping and storage prior to use; mission profiles while in use; phases between missions such as stand-by or storage; and transfer to and from repair sites and alternate locations. The environmental profile includes natural environmental profiles (e.g., temperature, pressure, etc.) and induced environmental profiles from things such as external sources (e.g., ECM, gunfire, acoustics, pyrotechnics), internally generated sources (e.g., heat, vibration, shock), and self-generated sources resulting from contact/interface with the environment. ASN(RD&A) best practices for DRMP development state that:

- Mission Profiles cover all system environments during its life cycle including operational, storage, handling, transportation, training, maintenance and production.
- Mission Profiles are defined in terms of time (duration and sequence), level of severity, and frequency of cycles.

- Mission and System Profiles are detailed by the Government and contractor, respectively, based on natural and induced environments (e.g., temperature, vibration, electromagnetic impulses, shock and electrical transients).
- Profiles are the foundation for design and test requirements from system level to piece parts, including COTS/NDI.
- DRMP environmental profiles should not be simply extracted from MIL-HDBK 810, "Environmental Test Methods and Engineering Guidelines," 31 July 1995.
- Mission Profiles should not be based on average natural environmental conditions; more extreme conditions may more accurately reflect operational requirements in the place/at the time of use, such as indicated by MIL-HDBK-310 "Global Climatic Data for Developing Military Products," 23 June 1997 and the National Climatic Data Center.

DRMP guidance documents *do not* imply or direct that a DRMP should indicate, detail or otherwise constrain (beyond the impact of mission-specific conditions) the material solution, engineering design, or operational employment of a capability. The scope of a DRMP also excludes justification for a proposed concept/capability/system and any presentation of prospective military utility in an operational context (as is common in the vignettes of concept development proposals and the tactical situations normally associated with CONOPS). A DRMP *does* focus on system boundaries and interfaces with "outside systems." In 2002, ASN (RD&A) identified the relationship between the DRMP and other acquisition documents in this way: "The DRMP or elements of a DRMP are normally addressed in the following planning and contract documents: Mission needs statement (MNS), operational requirements document (ORD), CONOPS, acquisition plan (AP), systems engineering management plan (SEMP), TEMP, AoA, and Performance Specifications." This statement clearly identifies a sequential development process in which the DRM establishes a foundation for subsequent development of CONOPS — implying that the two are different, and that the DRM scope is narrower than that of a CONOPS. This paper recommends that DoD guidance be interpreted to limit the DRMP role to that of an authoritative source of functional and environmental considerations for the development of subsequent documents, and that the DRMP should not be tailored to subsume the content or role of other documents.

4.3. *Concept development proposal*

The Navy Concept Generation and Concept Development Program, as detailed in OPNAV Instruction 5401.9, addresses "The encapsulation of ideas into a coherent structure to pursue potential solutions; vetting and validating ideas through analytical studies, workshops, experimentation, war games, and, when required, live force experiments; transition of solutions to responsible agencies for action and to enable implementation." The concept generation process feeds concept development with candidate topics in the form of proposals, often formatted as "white papers."

Some of the concept development activities detailed in OPNAVINST 5401.9 necessarily form the foundation for further engineering development by the DoD acquisition community in cases where the process is sequential. The instruction offers examples of a Concept White Paper as well as general guidance for format and content. Topic headings include: Executive Summary, Purpose, Scope, Military Problem and/or Opportunity, Required Capabilities, Solution, Risks and Mitigation, and Considerations. It is also recommended that a Concept White Paper should conclude with a Plan of Action and Milestones (POA&M). While the content of a Concept White Paper reflects similarity with many variants of CONOPS, its purpose is quite specific to articulating a concept for future capabilities and OPNAVINST 5401.9 specifically states that the concept generation and concept development (CGCD) process does *not* develop CONOPS.

4.4. *Operational concept description*

The American National Standards Institute and American Institute of Aeronautics and Astronautics guide for the Preparation of OCDs (ANSI/AIAA G-043-1992; under revision in 2011) identifies operational concept description as a *technique* that results in an OCD. The purpose of the *technique* is to:

- Describe the system characteristics from an operational perspective.
- Facilitate understanding of the overall system goals with users (including recipients of the products of the system where applicable), buyers, implementers, architects, testers, and managers.
- Form an overall basis for long-range operations planning and provide guidance for development of subsequent system definition documents such as the system specification and the interface specification.
- Describe the user organization and mission from an integrated user/system point of view.

The guide goes further to state that the OCD (document) should be developed during concept definition, should be a precursor to system specifications and can serve as a tool in the evaluation of system design. It should also "...serve as a reference during system requirements analysis and design phases to provide the necessary framework within which the proposed system design and implementation alternatives can be evaluated." More specifically, section 2.2.2 of the ANSI/AIAA guide states that "The OCD provides a mechanism to trigger questions and raise issues regarding user-related requirements/design trades." The reader is encouraged to refer to ANSI/AIAA G-043-1992 (1992) for a more detailed description of the purpose and merit of an OCD — both as a process and a document. The AIAA website for the status of the 2011 OCD update is: www.aiaa.org/tc/se/html/aiaa_ocd_guide.html. An Operational Concept Description is also identified in a Data Item Description (DID) generated by the U.S. Navy Space Warfare Systems

Command (DoN, 2000). Identified as DI-IPSC-81430A, it offers no reference to the ANSI/AIAA guide previously mentioned, but identifies similar purpose, content, and format. Of particular interest, it offers a more concise outline for an OCD (document) than the ANSI/AIAA guide, and adds elements specific to DoD applications. It is a broad and detailed framework that lends itself well to tailoring, as has been done by a company called Solid Thinking Corporation (www.solid-thinking.org) to act as a framework for the development of acquisition CONOPS for the DoD.

5. Analysis of Suitability for the Development of SoS-based Capabilities

Given that the development of a SoS-based capability is often conducted outside the normal DoD acquisition framework, the applicability of many of the documents here may be challenged simply on the basis of DoD and service-specific policy — *there may be no applicable requirement to develop them*. However, the application of systems engineering best practices should not be abandoned due to a policy loophole. Each of the documents introduced earlier in this document offers a potential (if ill-suited) solution for capturing an operational context for early SoS development activities. The recommended content and format for each of these documents was reviewed for potential service in this role. This analysis focused on content and format proscribed for these documents in DoD and U.S. Navy guidance. The unique aspects of each document, especially as they might benefit a SoS development effort, are detailed in the paragraphs that follow.

Operational or "Fleet" CONOPS offer a comprehensive description of capabilities and systems being released (or soon to be released) for operational use. They include a letter of promulgation, an executive summary that addresses non-material aspects of operations and support of a system, and a clear statement of the purpose of the document. Individual sections are dedicated to issues associated with doctrine, organization, training, materials, logistics, personnel and facilities (DOTMLPF), operational scenarios (warfighting CONOPS only) that demonstrate how a capability or system will be employed, and perceived requirements for operations and experimentation to validate the Fleet CONOPS. Operational CONOPS, however, focus only on capabilities that are to be fielded within the FYDP and which have entered latter phases of engineering development. Fleet CONOPS do not address programmatic or technical risks associated with development activities, they do not offer detailed planning for research and analysis to inform engineering trade decisions, and they do not develop a warfighting gap as justification for a capability (although it may enter the discussion as a necessary context for introducing a new capability to fleet operators).

Acquisition CONOPS are developed for MDAPs in satisfaction of the Clinger–Cohen Act, and follow a similar format to that of a Fleet CONOPS. However, they differ significantly in focus as they are intended to inform the *development and* *sustainment* of a *single* system or platform. They identify assumptions to address uncertainty, introduce limitations to address programmatic and technical risk, and identify as constraints any aspects of the problem or solution-space that are considered intractable. Additionally, acquisition CONOPS identify interoperability aspects defined by the existing operational environment (e.g., legacy and soon-to-field systems) that must be considered during system design. Unique in an acquisition CONOPS is a discussion of a warfighting gap that substantiates a user need and justifies the development of a new system. Because an acquisition CONOPS is one document among many mandated for MDAPs, it captures only a small subset of valuable information necessary for technology development and engineering development activities that, in a SoS-based capability, spans *multiple* systems and platforms. For instance, an acquisition CONOPS need not include a plan for analysis and experimentation activities — these are the purview of separate documents such as a test and evaluation strategy, a TEMP, and a modeling and simulation plan. Similarly, an acquisition CONOPS may introduce a functional profile (intended for operational planning and sufficiency considerations), or an environmental profile (a written description of general operating conditions) for the intended system, but it is usually limited in detail and may be augmented by a DRMP.

A DRMP or DRM is not required by statute and is not consistently employed across Navy systems commands. It may, however, be employed to augment an acquisition CONOPS with much greater detail on the functions that a system must perform (or have performed on it) and environmental conditions to which it will be exposed during shipping, maintenance and operation. Often presented in a tabular format, the DRMP offers a profile of conditions associated with a representative mission that may be referenced for purposes of design. It is perhaps the most well named and tightly focused product introduced in this paper, but its tight focus presents a limitation in application to a SoS-based capability. Specifically, in the context of a MDAP, topics such as a related warfighting gap, operational employment considerations, sustainability aspects (e.g., DOTMLPF), programmatic and technical risk, or plans of action for analysis and experimentation are addressed in other documents. Additionally, within a MDAP, the DRMP is developed from the perspective of a single system or platform — rather than that of a composite capability achieved through a design that is distributed across multiple platforms or systems.

A Concept Proposal precedes logical analysis, technology development and establishment of a MDAP that ultimately delivers an operational system to the warfighter. A concept proposal may identify either a warfighting gap or an *opportunity* to achieve a warfighting advantage as justification for considering the development of new systems. The guidance for a Concept Proposal is unique in that it recommends that operational scenarios should address how the system adds value to existing systems and organizations, and what the system(s) will do under boundary conditions and degraded operations (in addition to content otherwise shared with many CONOPS variants). Since the avenue for delivery of new systems to the warfighter predominantly runs through MDAP offices,[f] a Concept Proposal attempts to identify programmatic and development risks that may challenge the transition of a new technology or system to the MDAP(s) responsible for EMD activities, fielding and lifecycle support. These topics are not addressed in the development guidelines for acquisition or Fleet CONOPS. Specifically, a Concept Proposal may concern itself with whether the desired capability will work operationally (i.e. it may be technologically feasible and demonstrable, but incredibly complicated and/or difficult to employ), whether it can be built or developed within reasonable budget and schedule constraints (i.e., a capability that cannot be developed in time to meet a need may be rendered obsolete prior to introduction), whether organizational barriers exist that may preclude successful development and/or fielding, and whether the capability will be accepted by the end users and operators (i.e., what conflicts and resistance might complicate adoption of the system or capability). A Concept Proposal also incorporates a plan of action and milestones that identifies stakeholders; establishes teams and membership; details requirements for studies, experimentation and demonstration events; reflects the collection, analysis and presentation of findings; and highlights resource requirements for near-term activities. A Concept Proposal does not identify a solution (e.g., a technology or a functional decomposition and physical allocation) and is therefore inadequate as a guidance document for technical or engineering development activities.

An Operational Concept Description is an industry recognized process and document format that captures many aspects addressed in acquisition and Fleet CONOPS and has latitude to incorporate the content attributed to a DRMP. The guidance for an Operational Concept Description is superior in its detail, especially in its treatment of impacts to the user, acquirer, developer and support agencies during development. Similarly detailed is guidance for addressing supportability aspects, impacts to existing operations and systems, and organizational realignment that might be required — roughly equivalent to DoD DOTMLPF considerations. A section dedicated to analysis of the proposed system (i.e., performance characterization) is uniquely suited to the development of SoS-based capabilities in that it focuses on advantages and limitations, as well as alternatives and trade-offs considered. The Operational Concept Description is also unique in that it calls for functional flows diagrams, content that offers greater technical detail than either acquisition or Fleet CONOPS, and far exceeds the scope and depth of a Concept Proposal.

[f] Admittedly, this is true even for capabilities achieved through SoS designs, while the constituent MDAPs may be responsible for the development, modification and fielding of a constituent systems, the development and fielding of the *SoS-based capability* has not been associated with, or assigned to, a single MDAP.

6. Creating an Operational Context for Early SoS Development Activities

In the final analysis, not one of the documents reviewed here is independently adequate as a means or product for capturing an operational context for development of complex, SoS-based capabilities. They do, however, each have unique and applicable content that can be combined into a new product that is ideally suited for articulating a common operational perspective on an advanced capability. Such a comprehensive vision is required to guide simultaneous concept development, technology development, and engineering/manufacturing development previously identified as the early Systems Engineering activities associated with exploration and exploitation of the SoS solution space.

An enhanced *OCD* is offered as a solution for creating and capturing an operational context for SoS-based capability development efforts within DoD. The "OCD" title easily distinguishes the new document from the myriad variants of CONOPS already in use, avoiding much of the aforementioned friction and angst associated with documents bearing the "CONOPS" moniker. The OCD recommended in this paper is unique in content and format, but remains true to the definition of an OCD detailed in the Handbook of Systems Engineering and Management and the *purpose* of an Operational Concept *Description* presented in the ANSI/AIAA standard.

OCD Title and Content: The title of this document — OCD — derives from industry and U.S. Navy guidance for capturing an operational context for system and capability development activities. An OCD is described in the Handbook of Systems Engineering and Management, as well as ANSI/AIAA G-043-1992. The content of this document has been expanded to adequately address the concept development, technology development and engineering development efforts that occur simultaneously and iteratively during the exploration and maturation of SoS solutions. Since these SoS-based capabilities may be developed outside the purview of an overarching MDAP, this document incorporates useful information that would otherwise be the purview of other acquisition processes and documentation (e.g., concept proposals, capability-based analyzes, AoA, capability development documents, and acquisition CONOPS among others).

OCD Purpose: The OCD is intended as both a framework for collaboration and a knowledge management tool. It should be used to obtain consensus among the acquirer, developer and support and user agencies regarding the operational concept for a proposed SoS-based capability. It is intended to ensure a common understanding of the operational context in which a SoS-based capability is to be employed. The document should serve as a repository for results from performance analysis and engineering trade decisions to provide a foundation for subsequent development of Fleet CONOPS and tactics. It is intended to inform (or reflect, as appropriate) system and interface specifications and to serve as a reference for the development of operationally representative scenarios for use in model-based development and performance characterization activities such as live demonstrations and/or formal test and evaluation programs.

OCD Relationship to Other Documents: The OCD may leverage existing documentation such as platform-specific CONOPS, tactics techniques and procedures (TTPs), analysis products, requirements documents, trade studies, design reference missions, or technical specifications for system performance. The OCD may serve to align existing documents in the context of a new capability by addressing new interfaces and functions not captured by legacy documentation. The OCD will likely identify new capability-specific requirements that must be satisfied by the constituent systems, and will therefore inform and influence updates to existing requirements documentation — potentially through a common capability-specific annex. The OCD will offer insight into coordination that must occur to verify capabilities and validate employment concepts for the SoS-based capability. The integration of modeling, simulation, analysis, and test activities across the constituent systems may draw from, or influence, existing modeling and simulation (M&S) and test and evaluation (T&E) plans within the associated program offices. The OCD will also identify higher-level, integrated functions that require the participation of two or more constituent systems in a build-up approach to a full capability evaluation. While such events should be described in the OCD, a separate integrated T&E planning document at the SoS level will most likely be required to adequately manage the capability characterization activities. SoS-level documents such as a "capability annex" or a "capability characterization plan" are offered as prospective companion documents to the OCD, but will not be further developed in this paper.

OCD Content and Organization: The enhanced OCD proposed in this paper represents a compilation of relevant content from documents that span concept development, technology development and engineering/manufacturing development activities. The organization of the OCD is outlined below with guidance for content, format, and a notional page count that is intended to necessitate clear, concise language and yield greater utility through readability. Although the page count is a function of the number of systems and employment modes involved in delivering the capability, the 50-page goal was achieved for a capability involving four systems and four employment modes in the first application of this guidance. Use of appendices is encouraged as a necessary tool for reaching the page limit on the body of the document. Appendices should be a repository for deeper technical and tactical details such as system performance and mission planning considerations. The proposed OCD organization and content for a SoS-based Capability development activity is detailed below. Each recommended section of the OCD derives from one or more of the documents introduced earlier in this paper — this information is provided as each section of the OCD is introduced in the outline below.

- **Concurrence/Endorsement Page**
  - Derived from: CONOPS (variants).
  - Pages: One.

- ○ Signatures of concurrence/endorsement from program offices supplying constituent systems to the SoS, as well as organizations involved in development/research/analysis activities.
- ○ Identify author(s) and/or prime integrator responsible for document generation and maintenance.
- ○ *Comments*: *Not intended to be routed through operational or DoD acquisition channels for approval at service or OSD levels. This document is intended as the product of (and impetus for) a collaborative and rigorous systems engineering effort — not a process for authorizing such efforts.*

- **Record of Changes**
  - ○ Derived from: Naval Aviation Training Operations & Procedures Standardization.
  - ○ Pages: One.
  - ○ Specify by page number and provide a brief description of any changes made to the document after concurrence signatures were secured (i.e., last revision).
  - ○ Identify schedule for regular review and revision.
  - ○ *Comments*: *Changes should be distributed to all constituent program offices and supporting organizations. Review and revision is recommended at intervals of no less than* 18 *months*, *modified as necessary to address significant findings*, *engineering trades*, *etc.*

- **Executive Summary**
  - ○ Derived from: Fleet CONOPS.
  - ○ Pages: Four (maximum).
  - ○ Concept/Capability: Two page limit.
    - Warfighting gap being addressed.
    - Capability proposed.
    - Brief description of SoS solution (identify constituent platforms/systems/organizations).
    - Critical assumptions/limitations/constraints.
    - Brief review of the timeline for development and fielding.
  - ○ DOTMLPF impacts: Two page limit.
    - DOTMLPF considerations are often identified during complex system integration activities. The OCD can be used as a method for informing stakeholders of implementation and lifecycle support challenges that will ultimately fall to the constituent platforms and systems.
  - ○ *Comments*: *Information in the executive summary should derive from other portions of the OCD — no new information should be introduced in the Executive Summary.*

- **Document Overview**
  - Derived from: Operational Concept Document.
  - Pages: One.
  - Purpose of Document.
  - Title history and precedent.
  - Relationship to other documents.
  - *Comments*: *Wording may be incorporated directly from the paragraphs immediately above.*

- **Mission and Objectives**
  - Derived from: CONOPS (variants).
  - Pages: Eight — two per section, ideally.
  - Mission & Objective.
  - Target Set(s).
  - Threat(s).
  - Current systems/capabilities.
    - Description of current capability — NOT the shortfall or warfighting "gap".
  - *Comments*: *This section of the document should serve to provide background for the subsequent section* (*warfighting/capability gap*). *Liberal use of references is preferred to duplication of information in detail. Only information immediately relevant to the development of the capability* (*exploration of the SoS design trade space*) *should be incorporated here — not a full theater/ threat brief.*

- **Warfighting Gap**
  - Derived from: Concept Proposal.
  - Pages: One.
  - In the context of the previously defined mission/objective, a description of the current or future military PROBLEM for which there is no adequate solution given currently fielded or funded capabilities AND/OR an opportunity for significant advancement in warfighting capability that can be achieved through the modification and integrated application of existing systems.
  - *Comments*: *Reference to applicable Capability-Based Assessments,* "*trade studies*" *and other supporting documents is encouraged* (*if such products are available*, *and germane to the SoS-based capability being pursued*). *May include reference to pertinent strategic guidance*, *and related service-specific or Joint Concepts that also justify the development of the capability.*

- **Scope of the Development Effort**
  - Derived from: Concept Proposal.
  - Pages: Two.
  - Intended to constrain the problem and manage expectations/perceptions relative to prospective capabilities and the related solution space. Includes a general timeframe for capability development and fielding (by increment, if known). May serve to include or exclude aspects of the problem or solution.
  - Assumptions, Limitations and Constraints that are germane to the development of the SoS-based capability.
    - What threats are specifically NOT being addressed by the capability? (some justification for their exclusion should be offered).
    - What systems or performance is specifically NOT part of the solution space?
  - *Comments*: *This section should also clearly delineate the boundaries of the capability development effort. Although the modification and integration of existing systems can often produce new warfighting capabilities that exceed those of the constituent systems — those capabilities will likely field in increments* (*a step-wise approach to the complete capability*), *and performance of the extant systems may constitute a constraint on the engineering trade space that precludes achievement of a* "100% *solution.*" *Additionally,the asynchronous fielding of constituent systems may drive a change to capabilities delivered in any particular increment. Therefore, a minimum set of functions required to achieve a level of military utility in a given increment should be identified as interim goals* (*capability development and maturity indicators*) *during development.*

- **Concept/Capability Description**
  - Derived from: Concept Proposal.
  - Pages: Four.
  - Notional format: Two-Three pages of text and two one-half page pictures.
  - Identify the warfighting capability being pursued through a SoS-based solution.
  - Identify SoS constituent platforms/systems and characterize their functions in the context of the SoS-based capability.
  - Identify prospective employment modes (if more than one might exist) that help to frame alternative relationships between platforms/systems and variations on the composite capability delivered through the SoS design.
  - *Comment*: *Emphasize how platforms and systems*, *acting independently*, *cannot otherwise achieve the capability. A functional block diagram is encouraged as a method for representing the capability*, *with physical allocation to SoS*

constituent platforms/systems either embedded in the FBD, or captured in a subsequent figure.

- **Design Trade Space (Overview)**
  - Derived from: None (Added for SoS-based Capability Development).
  - Reference: Systems Engineering Best Practices.
  - Pages: One per aspect of the trade space.
  - Aspects of trade space may be addressed by constituent systems and interfaces, through roles and information exchanges, and should include critical technical parameters and, if known, associated levels of performance.
  - Deviations from current system functions and performance should be identified as new "delta requirements".
  - *Comments*:
    - *An entire Appendix is dedicated to design trade decisions and another to capability/performance characterization (i.e. test and analysis); therefore, this section should provide an overview only, but should be updated and informed by new information as appropriate.*
    - *The level of detail associated with information exchange and system-level "delta requirements" will increase as the SoS solution space is explored. This is necessarily an iterative process for SoS development and will necessitate many updates to this section of the document as engineering trades are made.*
    - *Currently fielded systems may out-perform MDAP threshold levels identified in technical specifications. Claiming this performance as fundamental to a new capability constitutes both a "delta requirement" (which should be modified in the constituent system's requirements documentation) and a programmatic risk that should also be identified in the "issues and risks" section of this document until properly resolved.*

- **Operational Scenarios**
  - Derived from: Acquisition and Fleet (Warfighting) CONOPS, Concept Proposal (vignettes).
  - Pages: Three per scenario.
  - Notional format (per scenario): One graphic (one-half page) and Two and one-half pages of text.
  - Mission/objective for new capability.
  - Mission success criteria.
  - Scenario content (examples; sequence/order as appropriate).
    - Prospective employment modes/methods/procedures/sequence.
    - Implied system performance (explicit/derived requirements).
    - Information exchange, command and control aspects, decision making.

- Reference to necessary mission planning or controls and displays (derived requirement).
- What the system should NOT do (degraded or fail-safe modes).
- How new system adds value to existing system(s)/organization(s).
- Operationally accurate (with respect to threat and associated vulnerabilities).
- How system accomplishes task/mission.
- Impact of operating environment.
- How capability will be employed (operator use) → feeds service exercises and experiments, operational assessments and (if applicable) test and evaluation.

◦ *Comments*:

- *Scenarios SHOULD focus on providing a clear and concise portrayal of how the new capability might be employed, and its warfighting merit/military utility.*
- *Scenarios SHOULD NOT attempt to detail the threat and blue-force lay-down for an entire theater, but should provide adequate detail for subsequent development of scenarios for modeling, simulation, test and evaluation purposes.*
- *Scenarios SHOULD NOT duplicate the (amplifying) information provided in other sections of this document, such as functional block diagrams, environmental conditions, etc.*

- **Functional Profile**
  - Derived from: Design Reference Mission Profile.
  - Pages: Two per unique employment mode, as applicable.
  - Notional format: Tables (preferred); outlines, flow-charts, etc. (optional).
  - A time scale of all unique functions that must be performed on or by the constituent systems to provide support for the SoS-based capability.
  - *Comments*:
    - *Should align with previously presented operational scenario(s), and provide much greater detail on required system functionality and performance.*
    - *Deviations from current system operation & support profiles should be highlighted as "delta requirements."*
    - *May make reference to, or be assembled from documentation associated with constituent systems.*
    - *If a DRM/DRMP has been developed for the capability, duplication is not recommended (the documents should be compatible and mutually supportive) — however, truly revolutionary capabilities may so advance (or challenge) current system functionality that new profiles may be required.*

- **Environmental Profile**
  - Derived from: DRMP.
  - Pages: Two per unique employment mode, as applicable.
  - Notional format: Tables (preferred); outlines, flow-charts, etc. (optional).
  - A time scale of all unique environments to which the constituent systems will be exposed while providing support/service/functionality to the SoS-based capability.
  - *Comments*:
    - *Should align with previously presented operational scenario(s), and provide much greater detail on required system functionality and performance.*
    - *Deviations from current system operation and support profiles should be highlighted as "delta requirements."*
    - *May make reference to, or be assembled from documentation associated with constituent systems.*
    - *If a DRM/DRMP has been developed for the capability, duplication is not recommended (the documents should be compatible and mutually supportive) — however, truly revolutionary capabilities may so advance (or challenge) current system functionality that new profiles may be required.*

- **Capability Characterization Strategy**
  - Derived from: None (Added for SoS-based Capability Development).
  - Reference (rough analog): Test and Evaluation Strategy.
  - Pages: Six (one page per topic).
  - Requirements for research and analysis necessary to characterize the performance of the SoS in the context of the desired capability.
    - Modeling and simulation.
    - System level testing.
    - System integration activities.
    - Operational experimentation.
    - Live demonstrations.
    - Related/additional studies.
  - *Comments*:
    - *This effort is unique to the development of a SoS-based capability.*
    - *This might be viewed as an early approximation of test and evaluation strategy with embedded modeling & simulation.*
    - *While early involvement of operational test agencies and T&E commands is both strongly encouraged and critical to the success of the capability development effort, it should be stressed and well understood that characterizing the performance of the SoS within the context of warfighting gap/operational scenario(s) is the purpose of these activities. Initial Operational T&E for the*

purpose of determining operational effectiveness and suitability may have to give way to an Operational Assessment and an Observation of Operational Capability for SoS-based capabilities (this is a topic for future research and innovation).

- **Action Plan (Plan of Action and Milestones (POA&M))**
  - Derived from: Concept Proposal.
  - Pages: One per constituent acquisition program, initially, with a goal of a single integrated development schedule.
  - An integrated master schedule (IMS) that spans constituent systems, development and integration efforts, and all activities related to capability characterization (see above).
  - A priority of recommended changes should be made that identifies the achievement of modules or increments of military utility (i.e. "capability worth fielding") – *a SoS perspective.*
  - *Comments: Maintaining alignment of the development efforts being conducted via each of the constituent system program offices (and contractors) may constitute the greatest workload and risk associated with a SoS development effort. This section of the document will likely demand constant monitoring and re-alignment. Ideally, a lead system integrator (organization or program) may be identified as responsible for the capability-specific IMS.*

- **Issues and Risks**
  - Derived from: Concept Proposal.
  - Pages: One per topic area — about 9 to 10 pages.
  - Expected challenges and obstacles.
    - Integration
      - What interfaces appear to be the most problematic?
      - How well defined is the functional decomposition and physical allocation?
      - Is requirements language clear?
    - Technological
      - Are technology development requirements well understood and documented?
      - Can the performance be achieved, and how quickly?
    - Organizational
      - Can fiscal and contractual obstacles be successfully addressed?
      - Can priorities be assigned/aligned across constituent systems and programs?

- Stakeholder and User Acceptance
  - Is the concept/capability well supported?
  - Will the capability be used, or are other alternatives available/preferred?
- Security Environment
  - Does the proper environment exist?
  - Can a proper environment be created, and on what timeline?
- Information Exchange and Interoperability
  - What modifications to existing channels and protocols are required?
  - Are timeliness and accuracy requirements well defined and achievable?
  - What additional load does the new capability constitute (i.e., bandwidth)?
  - Are new solutions required?
- Development/Modeling, Simulation and Analysis
  - Can existing models be leveraged, with or without modification?
  - What assumptions, limitations and constraints impact their suitability?
  - What new models, simulations or analysis tools are required?
- Demonstration/Live Test
  - What is the strategy for early T&E involvement, and have the operational test agency and (if appropriate) the Director of Operational Test and Evaluation (DOT&E) accepted the approach as adequate?
  - Will a capability characterization plan be developed?
- Operational
  - What is required to address necessary changes to doctrine, training, tactics and supportability in response to the introduction of the new capability?

◦ *Comments*: *This section is intended to collect initial areas of concern and risk. As the development effort proceeds, a more rigorous monitoring/management plan may be more appropriate to ensure that mitigation strategies and resolution efforts are executed to successful completion.*

- **Considerations (DOTMLPF)**
  - Derived from.
  - Pages: One per topic — about six pages.
  - Topics:
    - Doctrine and Operational Paradigm Shift
    - Changes to end-user organization(s)?
    - Training at the SoS level?
    - Leadership aspects of SoS employment?

- Personnel (numbers, skills, etc.)?
- Facilities (SoS integration/calibration)?

◦ *Comments*: *As with performance requirements levied on the SoS constituents by the capability, derived requirements for nonmaterial aspects of fielding, operations and support must also be considered. Since the development activities for a SoS-based design are usually executed through participating program offices and the MDAPs they support, all aspects of DOTMLPF are ultimately distributed as well-necessitating clear articulation and positive communication.*

- **Appendices**
  - Derived from: N/A.
  - Pages: As required.
  - Capability development content may include (but is not limited to).
    - Performance Characterization (results of analysis and testing).
    - SoS Design Trade Decisions.
    - Mission Planning Considerations.
    - Controls and Displays/Human–Machine Interface.
  - Administrative content may include (but is not limited to):
    - Terms.
    - Acronyms.
    - Points of Contact.
    - References.
  - *Comments*: *Appendices should be developed for any information or area of capability development effort that would otherwise encumber the main body of the document due to volume and/or level-of-detail.*

7. Future Research

This paper focused on identifying a method for establishing an operational context for the early systems engineering activities associated with SoS development as it is currently being pursued within the U.S. Navy. The author is currently mapping the content of the proposed OCD to the architecture products in version 2.2 of the DoD Architecture Framework, and finding a high degree of alignment with the new "capability" and "project" viewpoints. Such mutual support is highly desirable. There are a significant number of opportunities for additional research and innovation in the area of SoS development, management and sustainment. First, T&E in the context of SoS and complex capabilities was identified in this paper as a related but separate challenge. Although efforts are underway within the Navy to introduce "capability-based" and/or "mission-based" testing methods, the fact that the National Defense Industrial Association (NDIA) has established a committee to address DoD SoS challenges, and established working groups to address how best to conduct T&E in the context of SoS, indicates the growing appetite for new solutions in this area. Second, the capture and articulation of SoS-level requirements, to include communication and management of SoS requirements within the U.S. DoD and its constituent services, is another area where innovative solutions might be well received. Finally, should the proposed capability-specific OCD gain broad acceptance, it might be further improved by addressing topic areas normally covered by Technology Transition Agreements, Technology Development Strategies, and similar documents used within the established DoD acquisition process.

8. Summary

A detailed operational context is fundamental to the successful development of concepts, technology, and systems. The exploration of the engineering solution space available for the achievement of new warfighting capabilities through SoS-based designs is equally dependent on a well-constructed operational context. While concept-of-operations documents are often requested by name, this inaccurately implies a singular definition for CONOPS. The existence of numerous variants of CONOPS, and the organizational pedigree associated with each, can generate disagreement over authorship, ownership, approval authority, and the intended use of the document.

Starting with operational and acquisition CONOPS variants, this paper has identified a number of documents commonly used within the U.S. DoD for capturing the operational context for analysis, system development and employment. A comparison of the content and format associated with each of these documents revealed content that was inconsistent across the documents, but otherwise critical to capturing the operational context during early systems engineering activities. The comparison served to identify the shortfalls of each document in application to the more broad and challenging task of SoS-based capability development as it is practiced in DoD today. A capability-specific OCD was constructed and recommended as a catalyst and framework for SoS development as well as a repository for analysis products and engineering trade space decisions. The content and format of the OCD ensures that it is compatible with subsequent development of CONOPS by either "acquisition" or "fleet" organizations — making it a worthwhile investment that supports transition of advanced capabilities to the warfighter. The recommended capability-specific OCD may, in fact, be viewed as a superior analog to the "preliminary" CONOPS mentioned (but not further defined or developed) in DoD Instruction 5000.2. Finally, the name *OCD* distinguishes the product from the many variants of CONOPS, CONEMPS and DRMs currently being applied (or misapplied) throughout DoD, avoiding misperception regarding content, authorship, ownership, and approval authority.

References

American National Standards Institute/American Institute of Aeronautics and Astronautics, *Guide for the Preparation of Operational Concept Documents*, ANSI/AIAA G-043-1992 (1992).

Chairman of the *Joint Chiefs of Staff, Joint Operations Concepts Development Process* (*JOpsC-DP*), Instruction CJCSI 3010.02B (2006).

Chairman of the Joint Chiefs of Staff, *Joint Capabilities Integration and Development System* (JCIDS), Instruction CJCSI 3710.01F (2007).

Conklin, J. E., *Dialogue Mapping: Building Shared Understanding of Wicked Problems* (John Wiley & Sons Ltd., 2005), pp. 3−40.

Dahmann, J., Rebovich, G., Lane, J. and Lowry, R., *IEEE A&E Systems*, **26**(1) (2011) 22−28.

Department of the Air Force and Secretary of the Air Force, *Air Force Concept of Operations Development* (Instruction 10-2801, Pentagon, Washington, DC, 2005), www.e-publishing.af.mil.

Department of Defense, Office of the Under Secretary of Defense for Acquisition, Technology and Logistics (USD(AT&L)), *Operation of the Defense Acquisition System*, DoDI 5000.2 (2008).

Department of Defense, Office of the Deputy Under Secretary of Defense for Acquisition and Technology, Systems and Software Engineering (ODUSD(A&T)SSE), *Systems Engineering Guide for Systems of Systems*, Version 1.0. (Washington, DC, 2008).

Department of the Navy and Fleet Forces Command (FFC), *CONOPS TO DOCTRINE: Shaping the Force From Idea Through Implementation. Fleet CONOPS Guidance Brief* (2006).

Department of the Navy and Fleet Forces Command (FFC), *Fleet CONOPS Writer's Guide*, Version 1 (2009).

Department of the Navy, Office of the Assistant Secretary of the Navy (Research, Development & Acquisition), *Technical Brief*: *Design Reference Mission Profile Development Guidelines*, TB # ABM 1002-03 (Pentagon, Washington, D.C., 2002) www.abm.rda.hq.navy.mil.

Department of the Navy and Office of the Chief of Naval Operations (OPNAV), *Navy Concept Generation and Concept Development Program*, Instruction 5401.9 (Pentagon, Washington, DC, 2010).

Department of the Navy and Office of the Chief of Naval Operations (OPNAV), *Developmental System Concept of Operations*, Instruction 5401.xx (DRAFT) (Pentagon, Washington, DC, 2010).

Department of the Navy and Naval Warfare Development Command (NWDC), *Guide for Navy Concept Generation and Concept Development Program*, Version 1.0 (2010).

Department of the Navy and Space Warfare Systems Command (SPAWAR), *Data Item Description for Operational Concept Document*, DI-IPSC-81430A (2000).

Ferris, T., *Insight* **12**(2) (2009) 49.

Institute of Electrical and Electronics Engineers, *IEEE Guide for Information Technology– System Definition — Concept of Operations* (*ConOps*) *Document*, IEEE Std 1362-1998 (R2007), (New York, NY, (2007).

International Council on Systems Engineering, *Systems Engineering Handbook*, Version 3.1, Seattle, WA (2007).

Lane, J. and Boehm, B., *Systems Engineering* **11**(1) (2008) 81−91.

National Research Council, U.S. Air Force Studies Board, *Pre-Milestone A and Early Phase Systems Engineering: A Retrospective Review and Benefits for Future Air Force Acquisition* (2008), http://www.nap.edu/openbook.php?record_id=12065&page=78(accessed on 28 March 2011).

Sage, A. P. and Rouse, W. B., *Handbook of Systems Engineering and Management* (John Wiley & Sons, Inc., 1999).

Skolnik, F. R. and Wilkins, P. G., *Johns Hopkins APL Technical Digest* **21**(2) (2000) 208−216.

United Kingdom, Ministry of Defence, Architecture Framework, MODAF M-10-013.

United Kingdom, Ministry of Defence, Acquisition Operation Framework: Capability Integration−Products.

United Kingdom, Ministry of Defence, *MoD Architectural Framework*: *Concepts & Doctrine Community of Interest Deskbook* (*Version 1.0*) (2005).

Biography

Bryan Herdlick is a member of the senior professional staff at the Johns Hopkins University Applied Physics Laboratory; he assists the Naval Aviation Systems Command with the development of advanced capabilities and complex systems. Bryan is an INCOSE Certified Systems Engineering Professional with additional certification in U.S. Department of Defense Acquisition (CSEP-Acq.). Bryan's academic background includes a BS in Electrical Engineering from the University of Dayton and a MS in Applied Physics from the Naval Postgraduate School. He is also a graduate of the U.S. Navy Test Pilot School and a distinguished graduate of the Naval War College. His collateral activities include supporting ABET on accreditation visits as a program evaluator volunteer and teaching Systems Engineering courses for the Johns Hopkins University Whiting School of Engineering.